

We claim:

1. A method of storing data in cells of a storage material having an inhomogeneous absorption having an inhomogeneous linewidth  $\Delta\nu_i$ , the method comprising:
  - 5       directing a reference pulse of electromagnetic radiation to the storage material;
  - modulating a data pulse according to data to be stored in the cells of the storage material;
  - 10      directing the data pulse of electromagnetic radiation to the storage material; and
  - 15      spatially-spectrally sweeping the reference pulse and the data pulse along a reference spatial-spectral trajectory and a data spatial-spectral trajectory, respectively, causing data to be stored in the cells of the storage material.
2. The method of claim 1, wherein the reference spatial-spectral trajectory and data spatial-spectral trajectory are the same.
3. The method of claim 1, wherein the reference pulse and the data pulse simultaneously illuminate each individual storage cell of the storage material.
- 20      4. The method of claim 1, wherein the reference pulse and the data pulse co-propagate to the storage material.

- 5        5. The method of claim 1, wherein a frequency sweep of at least one of the reference and data spatial-spectral trajectories is a linear sweep.
- 5        6. The method of claim 1, wherein a data bit is stored in a channel bandwidth  $\Delta v_{ch}$  and at least one of the spatial-spectral trajectories spans a frequency range that is larger than the channel bandwidth  $\Delta v_{ch}$ .
- 10      7. A method of storing a first data record and a second data record, the data records including one or more data bits, comprising:
  - 10      providing a storage material having an inhomogeneously broadened absorption of linewidth ( $\Delta v_i$ ) that is greater than the channel bandwidth ( $\Delta v_{ch}$ ) used to store a single data bit;
  - 15      providing a first reference pulse to the storage material, the first reference pulse having a first starting frequency within the inhomogeneous linewidth ( $\Delta v_i$ ) and a first starting spatial position on the storage material and following a first spatial-spectral trajectory that spans a first spectral region greater than the spectral channel bandwidth  $\Delta v_{ch}$  and less than or equal to the inhomogeneous linewidth  $\Delta v_i$ ;
  - 20      providing a first data pulse to the storage material, the first data pulse having a second starting frequency within the inhomogeneous linewidth ( $\Delta v_i$ ) and a second starting spatial position on the storage material , the first data pulse following a second spatial-spectral trajectory that spans a second spectral width that is greater than the spectral channel bandwidth ( $\Delta v_{ch}$ ) and

that is less than or equal to the inhomogeneous linewidth ( $\Delta v_i$ ), the first data pulse having a modulation corresponding to a first data record;

recording the first data record in the storage material by exposing the storage material to the first data pulse and the first reference pulse;

- 5 providing a second reference pulse, the second reference pulse having a third starting frequency within the inhomogeneous linewidth ( $\Delta v_i$ ) and a third starting spatial position on the storage material, the second reference pulse following a third spatial-spectral trajectory that spans a third spectral width that is greater than the spectral channel bandwidth ( $\Delta v_{ch}$ ) and
- 10 that is less than or equal to the inhomogeneous linewidth ( $\Delta v_i$ ), wherein the third spatial-spectral trajectory does not overlap the first spatial-spectral trajectory;

providing a second data pulse having a fourth starting frequency within the inhomogeneous linewidth ( $\Delta v_i$ ) and a fourth starting spatial

- 15 position on the storage material, the second data pulse following a fourth spatial-spectral trajectory that spans a fourth spectral width greater than the spectral channel bandwidth ( $\Delta v_{ch}$ ) and that is less than or equal to the inhomogeneous linewidth ( $\Delta v_i$ ), wherein the fourth spatial-spectral trajectory is the same as the third spatial-spectral trajectory, and the second data pulse
- 20 has a modulation corresponding to a second data record;

recording the second data record in the storage material by exposing the storage material to the second reference pulse and the second data pulse.

8. The method of claim 7, wherein:

the storage material comprises multiple cells for storing portions of the first and second data sequences; and

the multiple cells are exposed to the first reference pulse and the first

5 data pulse simultaneously.

9. The method of claim 1, wherein the storage material is Eu<sup>3+</sup>:YSiO<sub>5</sub>.

10. A method of storing data, comprising:

10 providing a storage material having multiple cells each capable of absorbing electromagnetic radiation within an inhomogeneous linewidth and having spectral channels each having a homogeneous linewidth within the inhomogeneously linewidth;

15 providing a reference pulse of electromagnetic radiation, the reference pulse exhibiting a frequency chirp within the inhomogeneous linewidth;

providing a data pulse of electromagnetic radiation, the data pulse exhibiting a frequency chirp within the inhomogeneous linewidth, the frequency chirp of the data pulse offset with respect to the frequency chirp of  
20 the reference pulse, the data pulse having a modulation corresponding to the data;

exposing the storage cells to the data pulse and the reference pulse while spatially scanning the data and reference pulses through the storage cells.

11. The method of claim 10, wherein the data pulse and the reference pulse simultaneously illuminate each storage cell.

5        12. The method of claim 11, wherein the frequency chirp of the reference pulse has a rate of change of frequency  $R_{\text{sweep}}$ , the data has a modulation bandwidth, and each storage cell is exposed to the reference pulse and the data pulse for a time duration greater than about the modulation bandwidth divided by  $R_{\text{sweep}}$ .

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13. A method of retrieving data stored in cells of a storage material having an inhomogeneous absorption having an inhomogeneous linewidth  $\Delta v_i$ , the method comprising:

15        directing a reference beam of electromagnetic radiation to the storage material; so as to generate a reconstructed data beam;  
              combining the reconstructed data beam with a local oscillator beam;  
              spatially-spectrally sweeping the reference beam along a reference spatial-spectral trajectory, wherein data is retrieved from the cells of the reference material.

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14. The method of claim 13, wherein the local oscillator beam is a portion of the reference beam.

25        15. A method of storing data in a storage material having an inhomogeneous linewidth, the method comprising:

storing a first data bit in a spatial cell of the storage material by exposing the spatial cell with illumination having a frequency within the inhomogeneous linewidth; and

storing a second data bit in the spatial cell by exposing the spatial cell  
5 with illumination within the inhomogeneous linewidth after a time greater than or equal to an excitation lifetime of the storage material.

16. The method of claim 15, wherein the illumination used to store the first data bit and second data bit includes a reference beam and a data  
10 beam, wherein the data beam is modulated according to the first bit and the second data bit.

17. The method of claim 16, wherein the reference beam and the data beam have a frequency offset.

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18. The method of claim 17, wherein the first data bit is stored by illuminating the spatial cell with the reference beam and the data beam within a dephasing time of the storage material.

20 19. An apparatus for storing and retrieving data from a storage material having an inhomogeneous absorption, comprising:

a laser that produces a laser beam having a frequency that sweeps through a frequency range;

a signal generator that generates a reference signal;

25 a data source that provides a data signal;

an acousto-optic modulator that receives the reference signal, the data signal, and the laser beam and generates a reference beam and a data beam, the data beam modulated by the data signal, wherein the data beam and the reference beam are co-propagating;

- 5        a scanner that scans the data beam and the reference beam across the storage material, so as to cause data to be stored in cells of the storage material; and

            a detector situated to receive the reference beam transmitted by a cell and a reconstructed data beam produced by the transmission of the

- 10      reference beam through the cell, the detector producing a heterodyne signal from the reference and reconstructed data beams, wherein the heterodyne signal has a modulation corresponding to data retrieved from the storage material.

- 15      20. The apparatus of claim 19, wherein the storage material is Eu<sup>3+</sup>:YSiO<sub>5</sub>.